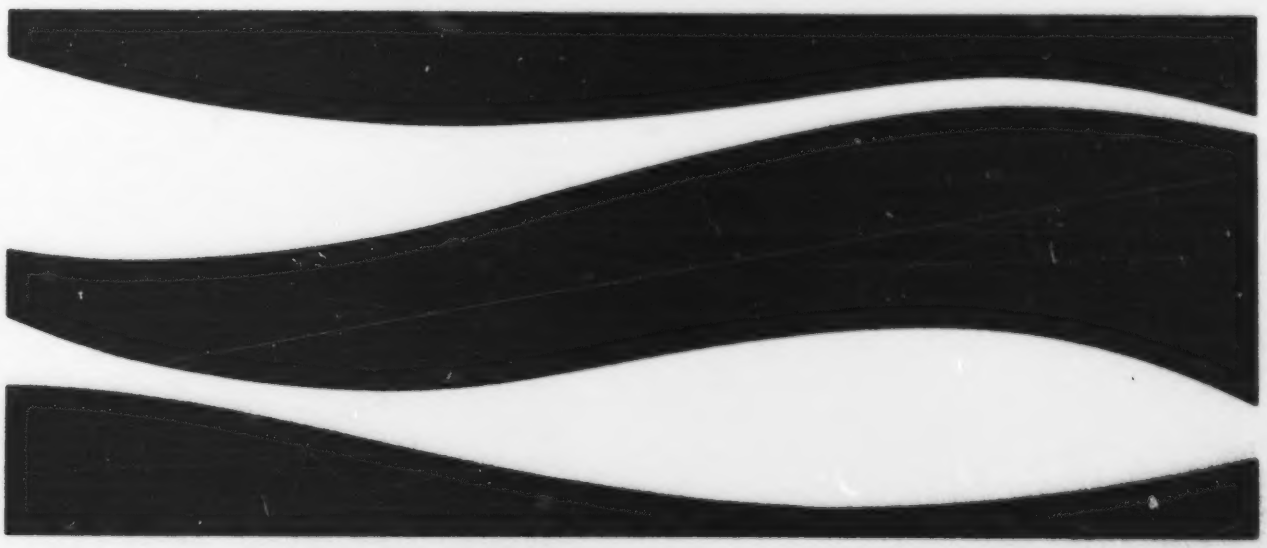
Province of British Columbia
Ministry of Environment
Fisheries Branch
Marine Resources Section

Information Report #7

Effects of the Methods of Harvesting and Transporting on the Quality of Farmed Chinook Salmon



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EFFECTS OF THE METHODS OF HARVESTING AND TRANSPORTING ON THE QUALITY OF FARMED CHINOOK SALMON

Information Report No. 7

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PREFACE

This report was prepared under contract with the Marine Resources Branch (now the Marine Resources Section, Fisheries Branch) of the Ministry of Environment.

This work was undertaken in support of the salmon farming industry in British Columbia. As well, it was intended to provide some guidelines for any regulations that may be developed by Provincial and/or Federal agencies.

The results of these analyses will provide some very practical and useful direction when salmon farmers are faced with the decision on what procedures to use for processing and handling. Specific recommendations for the farmer are to be found on page 25. Clearly, there is a requirement for further research on this subject and, in particular, where storage for a period longer than 48 hours occurs.

Suggestions for further work or similar studies are welcomed.

T. G. Halsey
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TABLE OF CONTENTS

	Page
SUMMARY	5
INTRODUCTION AND OBJECTIVES	6
EXPERIMENTAL PROCEDURE	7
I. SAMPLE COLLECTION AND STORAGE	7
II. SENSORY EVALUATION	10
A. Panel Training and Selection	10
B. Sample Evaluation	10
C. Statistical Analysis	12
III. BACTERIOLOGICAL EVALUATION	12
IV. CHEMICAL ANALYSIS	13
V. PROJECT STAFF	13
RESULTS AND DISCUSSION	14
I. SENSORY EVALUATION	14
A. Reliability Analysis	14
B. Main Effects	14
C. Effect of Gutting on Starved, Bled, 0°C Samples	17
D. Effects of Feeding, Bleeding, Storage Temperature and Storage Time	19
II. BACTERIOLOGICAL EVALUATION	21
III. CHEMICAL ANALYSIS	23
CONCLUSIONS	24
RECOMMENDATIONS	25
REFERENCES	25
APPENDICES	

LIST OF FIGURES AND TABLES

FIGURE		Page
1	Flow diagram of experimental conditions	9
2	Sensory scores of farmed chinook salmon stored at 0, 7 and 15°C	16

TABLE		Page
1	Main effects of feeding, bleeding, gutting, storage temperature and storage time on sensory scores of farmed chinook salmon	15
2	Effect of gutting on sensory scores of farmed chinook salmon (starved, bled, 0°C)	17
3	Mean sensory scores of starved, bled farmed chinook salmon (starved, bled) during storage	18
4	Gill odour scores of farmed chinook salmon stored at 0, 7 and 15°C	19
5	Gill appearance scores of farmed chinook salmon stored at 0, 7 and 15°C	20
6	Belly cavity scores of farmed chinook salmon stored at 0, 7 and 15°C	21
7	Bacteriological results for farmed chinook salmon stored at 0, 7 and 15°C	22
8	TMA-N analysis of farmed chinook salmon stored at 0, 7 and 15°C	23

LIST OF APPENDICES

APPENDIX	
I	Freshness Score Sheet for Farmed Chinook Salmon
II	Reliability Analysis of Sensory Scores
III	Photographs of Sensory Changes in Farmed Chinook Salmon Stored at 0, 7 and 15°C

SUMMARY

Salmon farmers in B.C. need to know whether their product should be processed immediately or within a few hours from harvest. In this study, farmed chinook salmon were examined for the effect of the following five factors on their sensory, bacteriological and chemical quality: feeding; bleeding; gutting; storage temperature; and storage time. Although neither feeding nor bleeding had a consistent effect on quality for up to 48 hrs. storage at 0, 7 or 15°C, the storage time was likely not long enough to demonstrate the advantages of these treatments. Gutting and storage at 0°C resulted in the highest quality for farmed chinook salmon.

However, considering the handling of this species in the round, at 0°C there is only a slight loss in quality for up to 48 hrs. storage. Round fish stored at 7°C remain of good quality for 48 hrs. but the bacterial load on the skin is substantial at this time. Round fish stored at 15°C undergo significant quality loss beyond 24 hrs. due to changes in gill odour, gill appearance and belly cavity.

INTRODUCTION AND OBJECTIVES

Although still in a phase of relative infancy, salmon farming in B.C. is rapidly developing into a viable adjunct to the traditional salmon fishery.

One of the major attributes of salmon farming is its capability of providing to the consumer a product of unusual freshness and quality which, due to logistical constraints, cannot practically be equalled by salmon harvested from wild stocks.

Unlike the traditional fishery where the time required in transporting the catch to the processing plant is subject to the vagaries of harvesting and transporting fish at sea and is usually measured in days, farm reared salmon may be processed immediately or within a few hours from harvest.

In common with wild stocks however, farmed salmon suffer the same vulnerabilities in terms of product deteriorations and fragility as fish harvested in the wild. If salmon farming is to develop into a viable industry in B.C. and compete profitably with sea-grown product or product cultured domestically elsewhere, it will be incumbent on farmers to handle and process their product in a manner conducive to maintaining the highest quality product possible. The foremost consideration for the farmer then is whether to process his product on-site or transport the unprocessed product to some centralized processing facility. Both procedures have advantages and disadvantages.

On-site processing will require the availability of many facilities, each constructed, equipped and managed in a manner that complies with existing guidelines and regulations for product handling, processing, storage and water and waste treatment to ensure product quality and safety.

The transport of unprocessed (round) or semi-processed salmon to a central facility will, on the other hand, result in some degree of quality deterioration dependent on conditions of time, temperature and previous handling systems used.

The objectives of this study are to:

1. Compare by sensory, microbiological and chemical analysis the quality of farmed chinook salmon processed immediately upon harvest to similar products held in the round under conditions simulating those to which the product would most likely be exposed during transport to a central processing facility.

2. On the basis of these data provide guidelines for the preprocessing handling and transport of farmed fish consistent with maintaining a high quality product.

Although each step in the handling of this product, from harvesting to final processing, will influence product quality, factors examined in this study were limited to five:

1. Feeding,
2. Bleeding,
3. Gutting,
4. Storage temperature,
5. Storage time.

These were selected on the basis of their effect on quality and in consideration of the logistics of handling a larger number of samples.

EXPERIMENTAL PROCEDURE

Four hundred and twenty farmed chinook salmon were harvested from a local salmon farm. Average weight of a sample of 15 fish was 1.16 kg and average length was 40.0 cm. The flow diagram in Figure 1 summarizes the experimental conditions and the number of fish studied under each condition. The starved, gutted, bled samples held at 0°C were included in this experiment as a standard against which to compare the effects of the various factors. Due to the large number of fish and the logistics involved in evaluating 140 fish at each of the storage times (12, 24 and 48 hours), samples were acquired and evaluated over a 4-week period rather than being acquired in one lot as suggested in the original proposal.

I. SAMPLE COLLECTION AND STORAGE

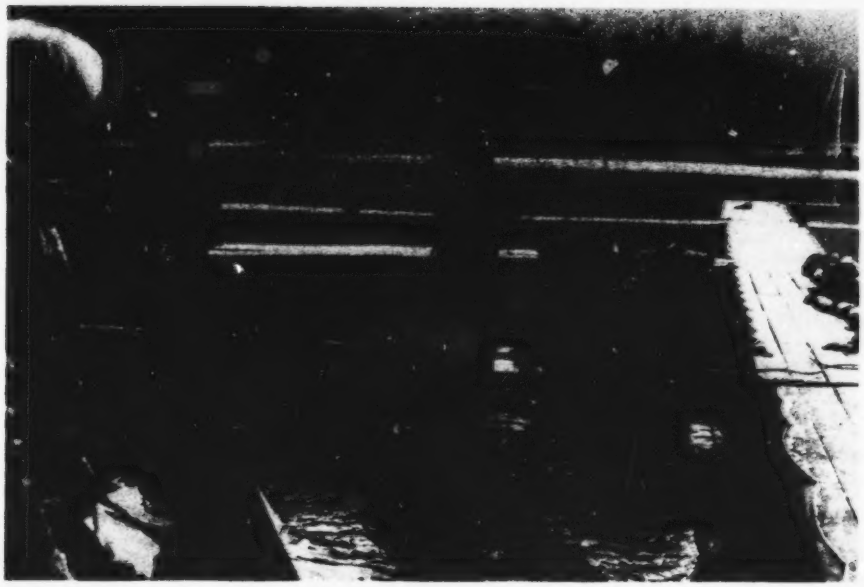
Fed samples were given 40% M & H ration (M & H Feeds, Inc., Surrey, B.C.) and 60% Nanaimo Farmer's Co-Op Formulation three times per day at a conversion rate of 2 to 1. When the salmon reached a weight of one-half pound, carotenoids were added to the diet at a level of 250 g per ton of M & H ration and 125 g per ton of Co-Op Formulation.

Starved samples were obtained by starving fish for 10 days after holding them on the above diet.

Each week, salmon were harvested from the rearing pen using a seine net, then removed, 20-30 at a time, using a dip net (Photograph 1). Subsequent processing steps are those described by Iversen (1978) for the processing of farmed salmon in Norway, with slight modifications. Samples were anesthetized by holding for 5 minutes in a tote filled with 7°C seawater which was saturated with carbon dioxide (Photograph 2). Unbled samples were placed directly into storage at the appropriate temperature as described in the next paragraph. Bled samples were slit in 3 places on one gill and held in a tank, flushed with seawater, until the bleeding stopped (approximately 10 minutes, Photograph 3). Gutted samples were prepared after bleeding by removing viscera, scraping the kidney and rinsing with seawater.

During transport to the laboratory, 0°C samples were held in ice (Photograph 4), 7°C samples were held on the vessel deck in covered totes and 15°C samples were held in the cabin in covered totes. Upon arrival at the laboratory, 0°C samples were held in ice in a 7°C room; for gutted samples, ice was placed in the belly cavity also. The 7°C samples were placed in a 7°C room and 15°C samples, in a 15°C room.

Samples were analyzed at 12, 24 and 48 hours. Sensory evaluation was carried out on all samples. Bacteriological and chemical analyses were carried out on 3 of the 5 fish used for each test condition.



Photograph 1. Harvesting chinook salmon from the rearing pen using a seine net. (25227.11)

Photograph 2. Anesthetizing chinook salmon using CO_2-saturated seawater. (25227.14)

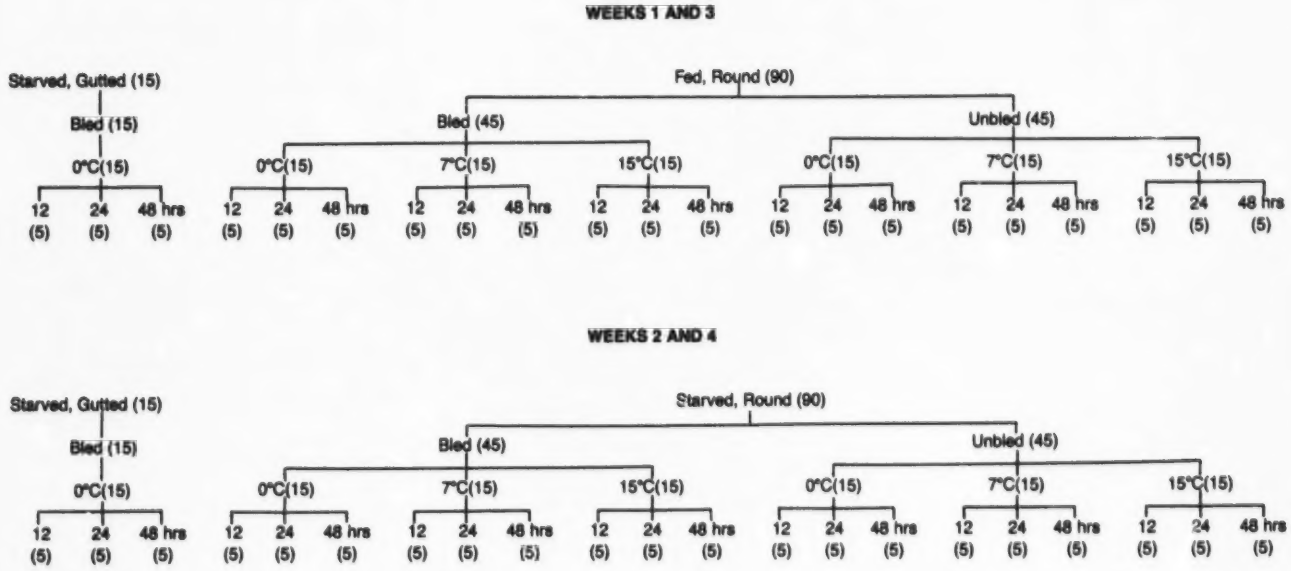


Figure 1. Flow diagram of experimental conditions. (Numbers in brackets show number of fish used.)

II. SENSORY EVALUATION

A. Panel Training & Selection

Prior to evaluating the experimental samples, a descriptive scoresheet was developed and nine experienced sensory panelists trained for the evaluation of farmed chinook salmon.

Various combinations of bled, unbled, gutted and round samples were stored at 0.5°C and 7°C for up to 26 hours. These were presented to the panel for discussion of quality changes throughout the storage period. The scoresheet used was developed from salmon grade standards used in B.C. and a scoresheet for raw, iced cod and haddock (Regenstein, 1983). Characteristics examined were eyes, skin, external texture/rigor, gill appearance, gill odour, flesh colour, and the appearance of the belly wall and belly cavity. During these sessions, a modified descriptive scoresheet was developed.

In order to select panelists for the experimental samples, bled, unbled, gutted and round samples were stored for 52 and 74 hours at 0.5°C and 7°C. These were scored by panelists using the descriptive scoresheet developed thus far. Panelists were then ranked according to their ability to score within $\pm$ 1 of the mean panel score for each characteristic.

B. Sample Evaluation

Characteristics being evaluated were grouped into 3 categories and 3 panelists were assigned to each category, based on the above ranking:

1. Eyes, skin, texture/rigor,
2. Gill appearance, gill odour,
3. Belly wall, belly blood vessels and belly cavity.

Experimental samples were evaluated by 2 of the 3 panelists per category. This method of evaluation was chosen due to:

1. The large number of samples,
2. The number of characteristics being assessed,
3. The availability of panelists, and
4. The likelihood of panel fatigue.

The sensory characteristics listed above in category form were slightly modified from those used during the training sessions. "Flesh colour" was included in the description for "belly cavity" and "belly blood vessels" was added to the list. The final scoresheet used for evaluation of experimental samples is given in Appendix I.

Samples were prepared for sensory evaluation by gutting, then rinsing the belly cavity. The fish surface was rinsed gently, only if blood was present. Samples were placed individually on trays in pre-randomized coded positions and evaluated under daylight fluorescent lighting using the scoresheet in Appendix I (Photograph 5). An extra sample, labelled as a reference (starved, bled, gutted and held at 0°C) was presented to the panel at each session prior to evaluation of the experimental samples. This extra sample was in addition to the 5 starved, bled, gutted 0°C samples evaluated blindly at each session as shown in Figure 1 (P. 5).

Photograph 3. Bleeding farmed chinook salmon. (25227.17)

Photograph 4. Farmed chinook salmon held at 0°C for transport to the laboratory. (25227.21)

Photograph 5. Sensory evaluation of farmed chinook salmon. (25226.9)

C. Statistical Analysis

Statistical analysis of sensory data was carried out using SPSS-X*.

Since any measurement involving judgements incorporates "true" measurement, "error" and "noise", reliability analysis was carried out to classify which data was analyzable and which was due mainly to error and noise. This analysis was done on all pairs of panelist for all characteristics examined (ie. eyes, skin, etc.). An arbitrary criterion of 50% was chosen as the level of variability in sensory scores which is accounted for by agreement between judges. Thus, for any particular characteristic, a pair of judges should have a coefficient of determination, r^2, of 0.50 (correlation coefficient, $r = 0.71$) to allow data analysis.

Analysis of variance (ANOVA) was performed ($P<0.05$) on those characteristics which fit the above criterion of reliability.

* Statistical Package for the Social Sciences.

III. BACTERIOLOGICAL EVALUATION

During the first half of the project, muscle samples were used for bacteriological analysis. It became clear by the end of Week 2 that the muscle was essentially sterile in all samples. For Weeks 3 and 4 skin swabs obtained prior to gutting were used rather than muscle samples.

For bacterial counts on the muscle, longitudinal cuts were made in the skin of the fish along the dorsal line and just above the belly cavity. Vertical cuts were then made through the skin at the anterior and posterior ends of the fish. This flap of skin was then removed and a template with a 10 cm^2 window was placed on the exposed flesh. A 10 to 15 g sample of muscle was removed, diluted with 0.1% peptone water and mixed for 2 mins using a Colworth Stomacher, Model 400. The homogenate was filtered in duplicate through an Iso-Grid system (HGMF method) from QA Labora-

tories, Toronto, Ontario. Filters were removed from the grid, placed on Standard Methods Agar with Congo Red indicator and incubated at 25°C for 72 hours.

For bacterial counts on the skin, the template was placed on the skin and the exposed part of the skin was swabbed. The swab was placed in 0.1% peptone water and the sample shaken 100 times through a distance of one foot. Samples were filtered, plated, incubated and counted as above. Counts were expressed as log CFU (colony-forming units) per cm^2 of skin.

For each condition, bacterial counts are reported as the mean for 3 fish, since fed and starved fish were evaluated in two lots (see Figure 1).

IV. CHEMICAL ANALYSIS

For trimethylamine-nitrogen (TMA-N) analysis, a longitudinal strip of muscle (approximately 2 cm × 2 cm × 15 cm) was removed from the dorsal portion of the fish following sampling for bacteriology. For each condition, ie. for each group of 3 fish analyzed for TMA, a constant weight of chopped muscle from each fish (varying from 10 to 25 g *between* groups) was pooled and mixed well. A 25 g sample of this composite was homogenized with 75 ml of 5% trichloroacetic acid for one minute using a Sorvall Omnimixer. The TMA-N content of the filtrate was determined by the micro-diffusion method of Beatty and Gibbons (1937) as further modified by Murray and Gibson (1972).

Since fed and starved fish were evaluated in two lots (see Figure 1), TMA-N values are reported as the mean of two values, each of which represents a composite value for three fish.

V. PROJECT STAFF

The following staff members contributed to this project:

Report Writing and Preparation		Ms. D. Nordin
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Program Advisor		Dr. G. Strasdine
Field Coordinator		Mr. D. Monteith
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Sensory Evaluation		Mrs. J. Mackey
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RESULTS AND DISCUSSION

I. SENSORY EVALUATION

A. Reliability Analysis

Results of reliability analysis on each pair of panelists who examined the 8 characteristics or parameters are given in Appendix II. This data indicates 5 of the parameters must be eliminated and only gill appearance, gill odour and belly cavity can be further analyzed based on $r^2 = 0.50$ (see Experimental Procedure II.C.). Thus, judging of eyes, skin, texture/rigor, belly wall and belly blood vessels showed disagreement in a haphazard way, which one must assume is mainly error or noise. This may have been due to the parameters being similar, not changing in a way related to the test or to the judges being unable to detect the changes.

In this particular study, judging disagreement may relate to:

1. Too short an exposure time — Changes in eyes and skin usually appear after a more extended storage period.
2. Varying activity of the fish prior to harvesting — Fish were observed to pass through rigor at many different postmortem times.
3. The uniformity of this particular product — Farmed salmon are more uniform in characteristics such as belly wall thickness than those in the wild.

Photographs in Appendix III show some of the changes that occurred over the 48 hr storage period.

B. Main Effects

The main effects of feeding, bleeding, gutting, storage temperature and storage time on sensory scores are presented in Table 1. For each effect, the samples being compared are indicated in this table. A breakdown of these effects is shown in Figure 2.

1. FEEDING

There was a significant overall difference between starved and fed fish for gill odour, gill appearance and belly cavity. Starved fish were scored slightly lower for gill odour and gill appearance and slightly higher for belly cavity. However, these differences are clearly due to the large number of samples evaluated and are not, in fact, marked or visible differences. This becomes obvious upon examination of the sensory scoresheet in Appendix I, which shows that a score difference of 0.4 (i.e. for belly cavity) is negligible relative to the descriptions given.

2. BLEEDING

There was a significant overall difference due to bleeding for gill appearance and belly cavity, the bled fish being scored slightly higher than unbled. This is not a marked difference, however. Gill odour was not significantly affected by bleeding.

3. GUTTING

There was a significant overall difference between gutted and round fish for gill appearance and belly cavity scores only. Gutted fish were scored higher than round fish. The mean scores indicate that in the case of gill appearance this is not a marked difference, whereas for belly cavity scores, the difference is substantial.

TABLE 1

Main Effects of Feeding, Bleeding, Gutting. Storage Temperature and Storage Time on Sensory Scores of Farmed Chinook Salmon

VARIABLES	PARAMETERS			SIGNIF. OF F
	Mean (SD) Cases	Mean (SD) Cases		
	STARVED VS FED (All samples)			
GILL ODOUR	6.9 (1.8) 356	7.1 (1.6) 358		0.000
GILL APPEARANCE	6.8 (1.8) 356	7.0 (1.6) 358		0.000
BELLY CAVITY	8.0 (1.6) 356	7.6 (1.7) 358		0.000
	BLED VS UNBLED (All samples)			
GILL ODOUR	7.0 (1.7) 360	7.0 (1.7) 360		0.229 NS
GILL APPEARANCE	7.0 (1.7) 360	6.8 (1.7) 354		0.000
BELLY CAVITY	7.9 (1.7) 360	7.7 (1.6) 354		0.005
	GUTTED VS ROUND (0°C samples only)			
GILL ODOUR	8.2 (1.2) 120	7.9 (1.1) 240		0.003 NS
GILL APPEARANCE	8.0 (1.0) 120	8.0 (1.1) 240		0.304 NS
BELLY CAVITY	9.6 (0.6) 120	8.4 (1.3) 240		0.000
	STORAGE TEMPERATURE (Round samples only)			
	0°C	7°C	15°C	
GILL ODOUR	8.2 (1.1) 240	7.1 (1.3) 238	5.7 (1.9) 236	0.000
GILL APPEARANCE	7.9 (1.1) 240	7.0 (1.4) 238	5.8 (1.8) 236	0.000
BELLY CAVITY	8.4 (1.3) 240	7.7 (1.5) 238	7.3 (1.9) 236	0.000
	STORAGE TIME (Round samples only)			
	12 hrs	24 hrs	48 hrs	
GILL ODOUR	8.2 (1.2) 238	7.1 (1.2) 240	5.7 (1.7) 236	0.000
GILL APPEARANCE	8.1 (1.2) 238	7.1 (1.2) 240	5.5 (1.6) 236	0.000
BELLY CAVITY	9.0 (0.9) 238	7.9 (1.3) 240	6.4 (1.6) 236	0.000

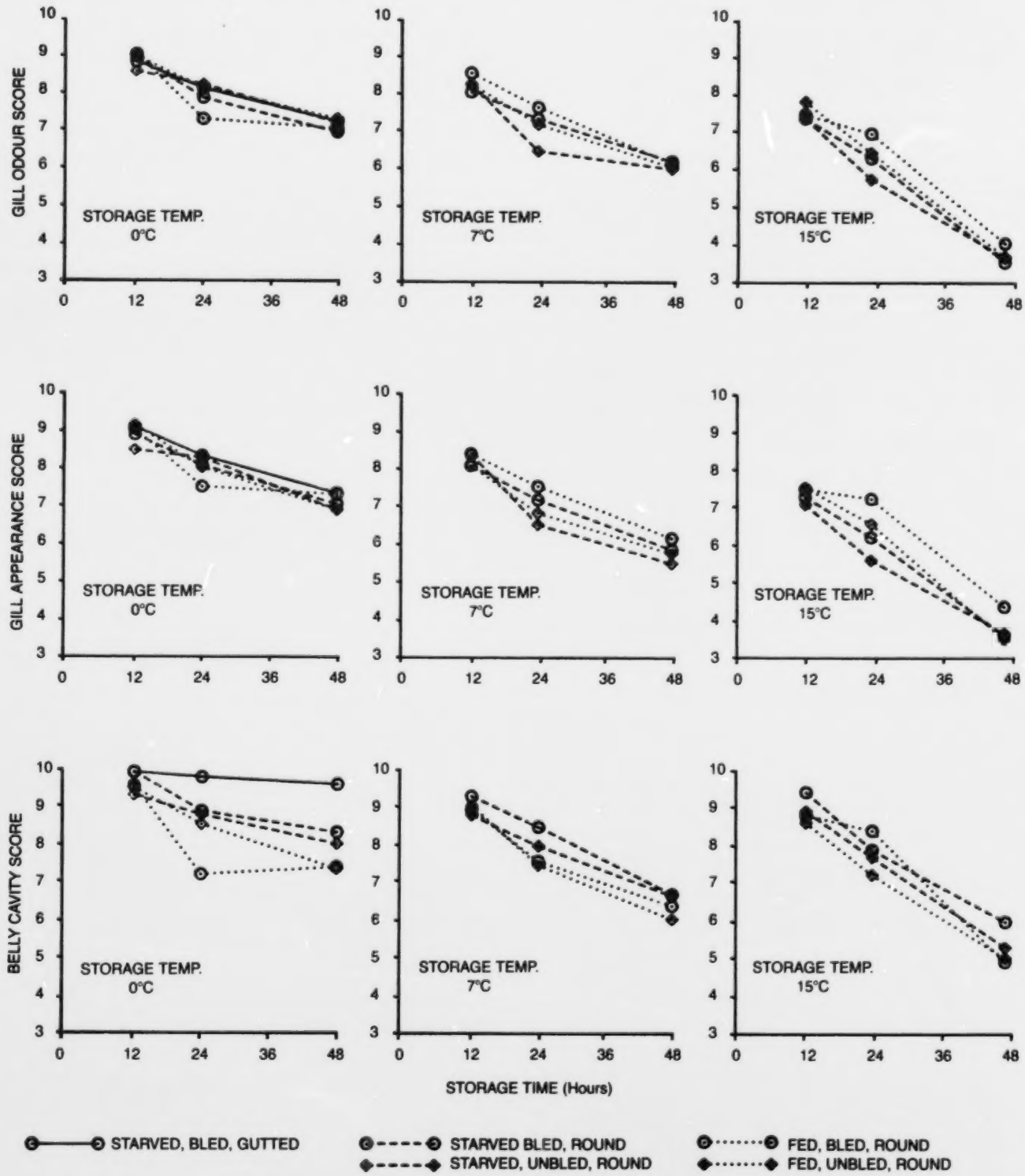

Figure 2. Sensory scores of farmed chinook salmon stored at 0.7 and 15°C. Each point represents the mean of 2 judgements on each of 10 fish.

4. STORAGE TEMPERATURE

The effect of storage temperature on gill odour, gill appearance and belly cavity was significant. A higher temperature lowered the scores for these parameters, with the greatest effect appearing in gill odour and gill appearance scores. The mean scores at each temperature indicate these are marked differences (see also Figure 2). Plates 2 and 4 in Appendix III show the effects of storage temperature on gill appearance and belly cavity, respectively.

5. STORAGE TIME

Storage time significantly lowered the overall scores for gill odour, gill appearance and belly cavity. This is a marked effect and is clearly shown in Figure 2. Gill odour and gill appearance were most affected by storage time.

C. Effect of Gutting on Starved, Bled, 0°C Samples

Table 2 shows the effect of gutting for starved, bled, 0°C samples only, which eliminates effects of feeding and bleeding. This data indicates that gutting had no significant effect on gill odour or gill appearance scores but resulted in a significantly and markedly higher score for belly cavity compared to round samples. Plate 3 and Plate 4, Photograph 14 in Appendix III show the physical difference in belly cavity for gutted and round samples held 48 hours at 0°C and 15°C, respectively.

A breakdown of the mean scores for starved, bled, 0°C samples is given in Table 3 and is shown graphically in Figure 2. The plot of belly cavity scores for 0°C shows that both round and gutted samples had similar scores at 12 hrs of storage but by 24 and 48 hrs, the gutted fish had markedly higher scores. At 48 hrs, however, the round, starved, bled fish still had a high and very acceptable score for belly cavity — 8.20, compared to 9.45 for gutted fish.

TABLE 2

Effect of Gutting on Sensory Scores of Farmed Chinook Salmon (Starved, Bled, 0°C)

VARIABLES	PARAMETERS		SIGNIF. OF F
	Mean (SD) Cases	Mean (SD) Cases	
	GUTTED VS ROUND		
GILL ODOUR	8.2 (1.2) 120	7.9 (1.1) 60	0.083 NS
GILL APPEARANCE	8.0 (1.0) 120	7.9 (1.6) 60	0.310 NS
BELLY CAVITY	9.6 (0.6) 120	8.9 (1.1) 60	0.000

TABLE 3

Mean Sensory Scores of Starved, Bled Farmed Chinook Salmon During Storage

STORAGE TEMP. C	STORAGE TIME hrs	STARVED BLED GUTTED Mean (SD) Cases	STARVED BLED ROUND Mean (SD) Cases
		GILL ODOUR	
0	12	8.80 (0.91) 40	8.95 (0.67) 20
0	24	8.10 (0.55) 40	7.85 (0.81) 20
0	48	7.23 (0.92) 40	6.95 (0.89) 20
		GILL APPEARANCE	
0	12	9.00 (0.88) 40	8.80 (0.83) 20
0	24	8.25 (0.93) 40	8.00 (0.79) 20
0	48	7.28 (1.06) 40	7.00 (0.85) 20
		BELLY CAVITY	
0	12	9.75 (0.44) 40	9.75 (0.44) 20
0	24	9.63 (0.54) 40	8.75 (0.97) 20
0	48	9.45 (0.71) 40	8.20 (1.06) 20

D. Effects of Feeding, Bleeding, Storage Temperature and Storage Time

Tables 4, 5 and 6 give mean sensory scores for the data presented in Figure 2. It is clear from this data that for each storage temperature and time, there is no marked difference in gill odour, gill appearance or belly cavity between round fish, whether starved, fed, bled or unbled. The standard deviations indicate that differences in Figure 2 which appear to be marked are, in fact, more apparent than real due to variation between panelists and between fish.

Since the mean belly cavity score for fed, bled, round fish at 0°C, 24 hrs storage was obviously low compared to the other 3 sets of round fish held at 0°C for 24 hrs, individual panelist's scores for each fish were examined. The low score and high standard deviation for this group is likely due to lower scores given by both panelists to 3 particular fish in that group compared to the other 7 fish.

All groups of round fish show a decrease in sensory scores for gill odour, gill appearance and belly cavity between 12 and 48 hrs of storage. This drop is least pronounced in 0°C samples and most pronounced in 15°C samples. The 0°C samples were still of very good quality at the end of 48 hrs storage (mean sensory scores of 7 to 8). At this time, 7°C storage still resulted in a good quality product (mean sensory scores of 6 to 7). For 15°C storage, however, samples are still of good quality at 24 hrs but of poor quality by 48 hrs (mean sensory scores of 3 to 4 for gill odour and appearance and 5 to 6 for belly cavity).

TABLE 4

Gill Odour Scores of Farmed Chinook Salmon Stored at 0°, 7°, and 15°C

STORAGE TEMP. C	STORAGE TIME hrs	STARVED BLED GUTTED Mean (SD) Cases	STARVED BLED ROUND Mean (SD) Cases	STARVED UNBLED ROUND Mean (SD) Cases	FED BLED ROUND Mean (SD) Cases	FED UNBLED ROUND Mean (SD) Cases
0	12	8.80 (0.91) 40	8.95 (0.67) 20	8.55 (0.94) 20	9.00 (0.92) 20	8.95 (0.83) 20
0	24	8.10 (0.55) 40	7.85 (0.81) 20	8.20 (0.70) 20	7.30 (0.80) 20	8.10 (0.55) 20
0	48	7.23 (0.92) 40	6.95 (0.89) 20	7.20 (0.89) 20	7.05 (0.83) 20	7.30 (0.66) 20
7	12		8.00 (1.21) 20	8.20 (1.01) 20	8.50 (0.89) 20	8.20 (0.70) 20
7	24		7.30 (1.22) 20	6.45 (1.00) 20	7.60 (1.05) 20	7.15 (0.75) 20
7	48		6.20 (1.58) 20	6.00 (0.84) 18	6.15 (0.59) 20	6.05 (0.89) 20
15	12		7.35 (1.53) 20	7.35 (1.27) 20	7.45 (0.94) 20	7.78 (1.60) 18
15	24		6.30 (1.49) 20	5.75 (0.55) 20	6.95 (1.36) 20	6.45 (0.69) 20
15	48		3.60 (0.68) 20	3.72 (0.57) 18	4.10 (1.07) 20	3.75 (0.85) 20

TABLE 5

Gill Appearance Scores of Farmed Chinook Salmon Stored at 0°, 7°, and 15°C

STORAGE TEMP. C	TIME hrs	STARVED BLED GUTTED Mean (SD) Cases	STARVED BLED ROUND Mean (SD) Cases	STARVED UNBLED ROUND Mean (SD) Cases	FED BLED ROUND Mean (SD) Cases	FED UNBLED ROUND Mean (SD) Cases
0	12	9.00 (0.88) 40	8.80 (0.83) 20	8.40 (1.05) 20	8.95 (0.89) 20	9.05 (0.69) 20
0	24	8.25 (0.93) 40	8.00 (0.79) 20	8.20 (0.62) 20	7.45 (1.00) 20	7.95 (0.68) 20
0	48	7.28 (1.06) 40	7.00 (0.85) 20	6.85 (0.99) 20	7.25 (0.85) 20	6.85 (0.49) 20
7	12		8.00 (1.08) 20	8.30 (1.13) 20	8.30 (0.92) 20	8.00 (0.86) 20
7	24		7.10 (0.91) 20	6.45 (1.32) 20	7.45 (1.00) 20	6.75 (0.91) 20
7	48		5.80 (1.32) 20	5.44 (0.86) 18	6.10 (0.64) 20	5.70 (0.99) 20
15	12		7.20 (1.40) 20	7.00 (1.26) 20	7.40 (0.88) 20	7.44 (0.78) 20
15	24		6.15 (1.27) 20	5.55 (0.69) 20	7.15 (1.31) 20	6.50 (0.76) 20
15	48		3.60 (0.75) 20	3.66 (0.77) 18	4.35 (1.09) 20	3.50 (0.69) 20

TABLE 6

Belly Cavity Scores of Farmed Chinook Salmon Stored at 0°, 7°, and 15°C

STORAGE TEMP. C	STORAGE TIME hrs	STARVED BLED GUTTED Mean (SD) Cases	STARVED BLED ROUND Mean (SD) Cases	STARVED UNBLED ROUND Mean (SD) Cases	FED BLED ROUND Mean (SD) Cases	FED UNBLED ROUND Mean (SD) Cases
0	12	9.75 (0.44) 40	9.75 (0.44) 20	9.15 (0.88) 20	9.40 (0.82) 20	9.35 (0.59) 20
0	24	9.63 (0.54) 40	8.75 (0.97) 20	8.65 (0.93) 20	7.10 (1.55) 20	8.40 (0.94) 20
0	48	9.45 (0.71) 40	8.20 (1.06) 20	7.90 (0.91) 20	7.30 (1.42) 20	7.25 (1.21) 20
7	12		9.15 (0.81) 20	8.65 (1.04) 20	8.80 (0.77) 20	8.90 (0.71) 20
7	24		8.35 (1.09) 20	7.85 (1.23) 20	7.45 (0.10) 20	7.35 (1.23) 20
7	48		6.60 (1.31) 20	6.56 (1.42) 18	6.30 (1.38) 20	5.95 (1.40) 20
15	12		9.30 (0.80) 20	8.80 (0.89) 20	8.70 (0.86) 20	8.50 (0.98) 20
15	24		7.80 (1.06) 20	7.60 (1.27) 20	8.30 (1.34) 20	7.15 (0.99) 20
15	48		5.95 (1.19) 20	5.28 (1.36) 18	4.90 (1.07) 20	5.00 (0.97) 20

II. BACTERIOLOGICAL EVALUATION

As discussed in Section III of Experimental Procedure, all muscle samples from Week 1 and Week 2 fish were essentially sterile, including those for fish stored for 48 hrs at 15°C.

Results of bacteriological evaluation of skin swabs from Week 3 and 4 fish are presented in Table 7.

Results for the round fish indicate that neither feeding nor bleeding had a consistent effect on skin bacterial levels. Data for the starved, bled, 0°C samples show that gutting also had no marked effect on bacterial numbers on the skin. Storage temperature and time, however, did influence the numbers of bacteria.

The 7°C samples had slightly higher counts throughout the storage time and especially at 48 hrs compared to 0°C samples. The 15°C samples had counts similar to 7°C samples for 12 and 24 hrs of storage but were slightly higher at 48 hrs.

Within the set of 0°C samples, storage time had very little effect on skin bacterial numbers. It is well known that at this temperature, bacteria multiply very slowly. At 7°C, bacterial numbers were essentially constant from 12 to 24 hrs of storage, then increased by more than one log cycle by 48 hrs. The 15°C samples also showed the most dramatic increase between 24 and 48 hrs of storage.

In summary, fish held 48 hrs at 0°C are virtually as clean on the surface as 12 hr fish. Some bacteria are present, but not in very large numbers. Fish held 24 hrs at 7°C or 15°C have slightly more surface bacteria, but counts are still low. By 48 hrs, 7°C and 15°C fish have 100,000 to one million counts/cm² of surface. At this point, it is crucial that processing include a surface cleaning or rinsing step to substantially reduce the bacterial numbers and prevent contamination of the final product.

TABLE 7

Bacteriological Results for Farmed Chinook Salmon Stored at 0°, 7°, and 15°C*

STORAGE TEMPERATURE	FEEDING CONDITION	FORM OF FISH	BLEEDING CONDITION	LOG CFU**/cm² skin STORAGE TIME (hrs) 12	24	48
0°C	Starved	Gutted	Bled	3.01	2.73	3.23
0°C	Fed	Round	Bled	2.58	2.28	3.20
			Unbled	3.38	3.15	2.52
	Starved	Round	Bled	3.00	3.08	3.04
			Unbled	3.30	4.07	4.40
7°C	Fed	Round	Bled	3.15	2.97	4.58
			Unbled	4.29	4.64	5.71
	Starved	Round	Bled	3.68	4.35	5.80
			Unbled	3.62	4.43	5.50
15°C	Fed	Round	Bled	4.00	>5.00	>6.00
			Unbled	3.78	>5.00	>6.00
	Starved	Round	Bled	3.92	4.19	6.91
			Unbled	2.97	3.40	5.84

* Each value represents 3 fish.
** Colony-forming units.

III. CHEMICAL ANALYSIS

Results of TMA-N analysis are presented in Table 8.

The data indicate that neither feeding, bleeding, gutting, storage temperature or storage time affected the muscle TMA content of the samples. All values are extremely low, considering that a value of 10 to 15 mg TMA-N/100 g muscle generally marks the onset of spoilage within fish muscle. It is expected that these samples contain virtually no TMA, in view of the limited storage time.

TABLE 8

TMA-N Analysis of Farmed Chinook Salmon Stored at 0°, 7°, and 15°C*

STORAGE TEMPERATURE	FEEDING CONDITION	FORM OF FISH	BLEEDING CONDITION	mg TMA-N/100 g muscle STORAGE TIME (hrs) 12	24	48
0°C	Starved	Gutted	Bled	2.1	1.6	2.0
0°C	Fed	Round	Bled	1.7	2.0	1.8
			Unbled	1.9	2.1	1.9
	Starved	Round	Bled	1.9	2.0	1.4
			Unbled	2.1	2.2	1.4
7°C	Fed	Round	Bled	2.0	2.0	2.0
			Unbled	1.9	2.0	2.1
	Starved	Round	Bled	1.7	1.8	1.5
			Unbled	2.0	2.3	1.7
15°C	Fed	Round	Bled	2.0	2.0	2.2
			Unbled	2.2	1.8	2.0
	Starved	Round	Bled	2.0	2.4	1.8
			Unbled	2.0	1.4	1.8

* Each value represents 6 fish.

CONCLUSIONS

1. Reliability analysis of sensory data indicated that only gill odour, gill appearance and belly cavity could be analyzed on the basis of assigning 50% as the level of variability in scores which is accounted for by agreement between judges.

2. Analysis of variance on sensory scores for gill odour, gill appearance and belly cavity to determine main or overall effects of feeding, bleeding, gutting, storage temperature and storage time showed that:

   a) Feeding had a significant, but not a marked effect, on all three sensory scores, resulting in a slightly higher rating for gill odour and gill appearance and a slightly lower rating for belly cavity.

   b) Bleeding did not have a significant effect on gill odour but had a significant effect on gill appearance and belly cavity, improving the ratings only slightly.

   c) Gutting did not have a significant effect on gill odour but had a significant effect on gill appearance and a significant and marked effect on belly cavity. Gutted fish were scored higher than round fish for both gill appearance and belly cavity.

   d) A higher storage temperature or longer storage time resulted in a significant and marked decrease in gill odour, gill appearance and belly cavity scores.

3. Although some marked effects were observed, the individual effects of feeding and bleeding in relation to storage temperature and storage time were inconsistent for gill odour, gill appearance and belly cavity. Further statistical analysis of specific groups of samples would reveal whether feeding or bleeding had a significant effect on sensory quality at any specific storage temperature or time.

4. Gutting had a significant and marked effect on belly cavity scores for starved, bled samples held at 0°C. Gutted fish were scored higher than round fish. After 48 hrs storage, however, round fish still had a high and very acceptable score for belly cavity.

RECOMMENDATIONS

1. Farmed chinook salmon can be stored at 0°C in the round for 48 hrs with only a slight loss in quality as measured by sensory, bacteriological and chemical means.
2. At 7°C this fish should be stored not more than 24 hrs in the round to obtain a high quality product and not more than 48 hrs in the round to obtain a good quality product. At 48 hrs, however, the large numbers of surface bacteria require that fish be rinsed well to reduce the bacterial load prior to processing.
3. At 15°C, farmed chinook salmon should not be held more than 24 hrs in the round, at which time some quality loss is apparent, specifically in gill odour and appearance. By 48 hrs, fish are of poor quality in terms of gill odour, gill appearance and belly cavity as well as bacterial load on the skin.
4. Gutting will ensure the highest quality for farmed chinook salmon stored at 0°C. However, if storage temperature and time are properly controlled, high quality fish can be obtained without gutting.
5. Although starvation and bleeding did not produce consistent effects in this study, these treatments would likely prove to be advantageous over a longer period of storage than the 48 hours used here.
6. To obtain highest quality fish, a storage temperature of 0°C will allow the most flexibility in storage time. A higher storage temperature can result in high quality fish as long as storage time is reduced.

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APPENDICES

APPENDIX I

Freshness Score Sheet for Farmed Chinook Salmon

SCORE	EYES	SKIN	TEXTURE AND EFFECT OF RIGOR MORTIS	GILL APPEARANCE	GILL ODOUR	BELLY WALL	BELLY BLOOD VESSELS	BELLY CAVITY	SCORE
10	Convex eye, black pupil, crystal clear cornea.	Bright irridescent colours, glossy. Transparent slime.	Flesh firm and elastic. Finger does not leave an impression when depressed. Body pre-rigor or in rigor.	Glossy, bright red or pink. Clear mucus.	Very fresh sharp odours (iodine, metallic seaweedy, seashore, shellfish) changing to less sharp fresh odours.	Thick belly walls, healthy fish	None	Good flesh colour (salmon pink), glossy. Belly cavity intact. Flesh firm.	10
									9
9			Flesh firm and elastic. Finger does not leave an impression when depressed. In or just passing through rigor.						
8	Slight flattening to completely flat. Elongated pupil, possible loss of pupil clarity.	Loss of brilliance of colour, some scale loss (up to 25%). Transparent slime.	Firm, elastic to the touch. Finger impression may recover more slowly.	Loss of gloss and brightness, slight loss of colour or slight darkening. Mucus thicker, may be cloudy.	Some loss of fresh odour. Freshly cut grass. Seaweedy and shellfish odour just detectable. May be no odour.	Thick belly walls.	Slight	Good flesh colour (salmon pink). Very slight evidence of belly burn (slight blush). Flesh firm, or may be less firm, possibly a few protruding ribs.	8
7									7
6	Slightly sunken. Elongated pupil, loss of pupil clarity, some cloudiness.	Dull general fading of colours, moderate scale loss (25-50%). Slime may be somewhat cloudy.	Softening of the flesh, finger indentations retained longer. Fish is limp.	Increasing discolouration of the gills, cloudy or discoloured mucus.	Definite loss of fresh odour. Slight oily, bready, malty, beery, yeasty.	Belly walls may be somewhat thinner.	Moderate	Flesh colour salmon pink to orange. Peritoneal lining thinner and up to 25% broken, flesh soft, some protruding ribs.	6
5					Off odours e.g. oily, slight compost.			Possible stained areas.	5
4	Sunken. Elongated pupil, cloudy to milky white pupil.	Further loss of skin colour. Thick yellow knotted slime with bacterial discolouration. Wrinkling of skin on nose.	Softer flesh. Finger indentations retained.	Brown or green discolouration or slight bleaching, yellow or brown mucus.	Strong off odours, composted grass, sweaty socks, fruity or chloroform like.	Thin belly walls.	Extreme	Definite discolouration (orange, brownish or reddish-orange). Moderate to extreme belly burn. Breakdown of tissue. Peritoneal lining almost destroyed.	4
3					Increasing strong off odours, rotten cabbage, stale turnips, sewage.			Protruding ribs. Flesh jelly-like.	3

APPENDIX I:

Reliability Analysis of Sensory Scores

	Mean	Standard Deviation	Minimum Score	Maximum Score	Number of Judgements	Coefficient of Determination
	x	s	Min	Max	n	r^2
Eyes						
P3	7.4	1.2	4	10	207	—
P7	7.2	1.0	5	9	35	—
P1	7.2	1.3	3	10	315	—
P2	7.8	1.0	4	10	277	—
P2 - P1	0.0	0.9	−2	2	175	0.32
P3 - P1	0.6	1.0	−1	3	105	0.24
P3 - P2	−0.2	1.1	−3	3	102	0.34
P7 - P1	1.7	1.0	0	4	35	0.29
Skin						
P3	7.9	1.2	4	10	207	—
P7	7.3	0.9	6	9	35	—
P1	7.4	1.2	3	10	315	—
P2	8.0	0.7	6	10	277	—
P2 - P1	0.1	0.9	−2	3	175	0.07
P3 - P1	0.9	1.1	−2	4	105	0.08
P3 - P2	0.4	1.1	−3	4	102	0.24
P7 - P1	1.8	1.2	−1	4	35	0.04
Texture/Rigor Mortis						
P3	7.5	1.3	4	10	207	—
P7	6.7	1.0	5	8	35	—
P1	7.5	1.4	4	10	315	—
P2	7.4	1.2	4	10	277	—
P2 - P1	−0.5	0.8	−3	1	175	0.55
P3 - P1	0.4	0.9	−2	2	105	0.39
P3 - P2	0.9	1.1	−2	5	102	0.46
P7 - P1	1.0	0.9	−1	3	35	0.36

P = Panelist

APPENDIX II (Cont'd)

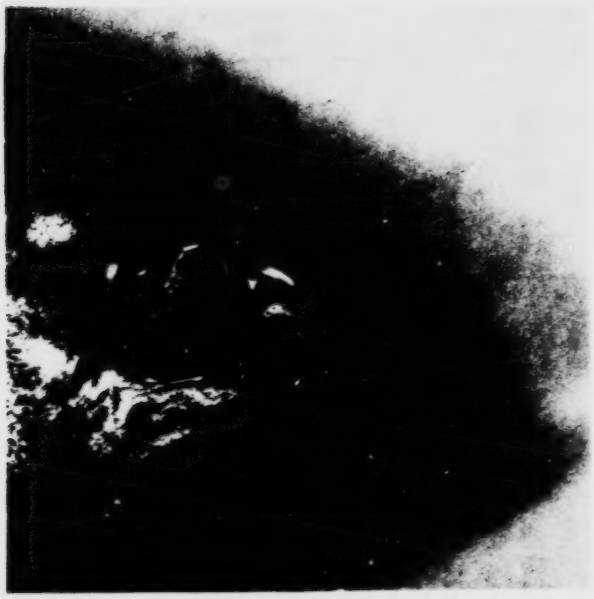
Reliability Analysis of Sensory Scores

	Mean	Standard Deviation	Minimum Score	Maximum Score	Number of Judgements	Coefficient of Determination
	x	s	Min	Max	n	r^2
Gill Appearance						
P5	7.2	1.7	3	10	314	—
P6	7.4	1.7	3	10	103	—
P4	6.9	1.7	3	10	417	—
P5 - P4	0.3	1.0	−4	3	314	0.66
P6 - P4	0.3	1.7	−5	4	103	0.35
Gill Odour						
P5	7.2	1.7	3	10	314	—
P6	7.4	1.6	3	10	103	—
P4	7.0	1.7	3	10	417	—
P5 - P4	0.3	1.0	−4	3	314	0.63
P6 - P4	0.3	1.8	−4	4	103	0.22
Belly Wall						
P8	9.9	0.4	7	10	172	—
P9	8.7	0.7	7	10	245	—
P7	9.1	1.2	5	10	417	—
P8 - P7	0.8	1.1	−2	4	172	0.00
P9 - P7	−0.4	1.2	−3	4	245	0.11
Belly Blood Vessels						
P8	6.9	1.0	5	9	172	—
P9	7.3	1.2	4	10	245	—
P7	6.9	1.1	4	10	417	—
P8 - P7	−0.3	1.0	−4	2	172	0.29
P9 - P7	0.5	1.0	−2	3	245	0.39
Belly Cavity						
P8	9.1	1.2	5	10	172	—
P9	7.9	1.7	4	10	245	—
P7	7.7	1.7	3	10	417	—
P8 - P7	0.9	1.0	−2	3	172	0.45
P9 - P7	0.4	1.2	−3	3	245	0.62

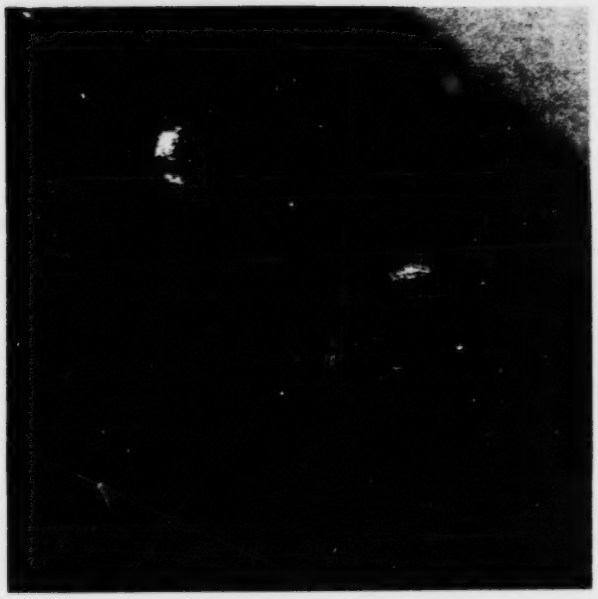
P = Panelist

APPENDIX III

Photographs of Sensory Changes in Farmed Chinook Salmon Stored at 0, 7 and 15°C

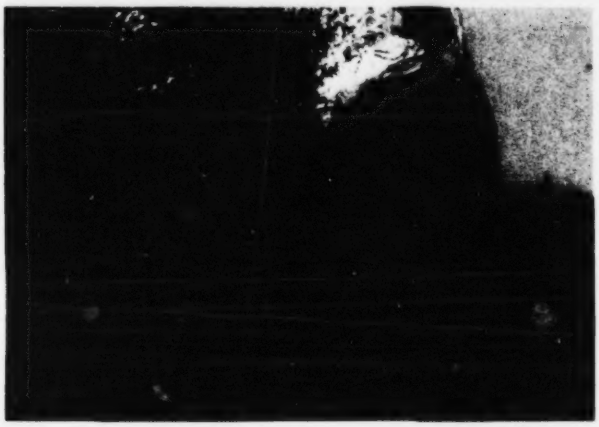


Photograph 6.
(25228.20A)

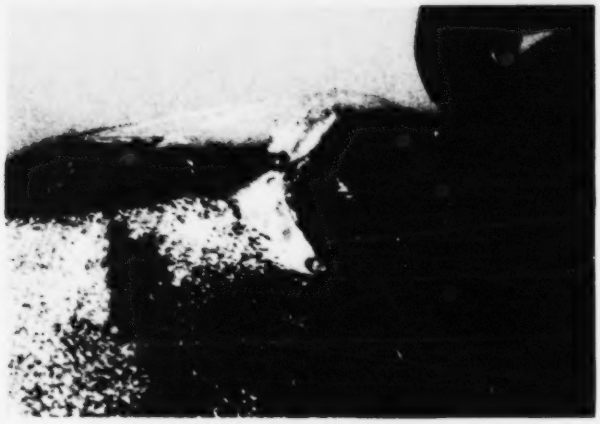


Photograph 7.
(25232.1A)

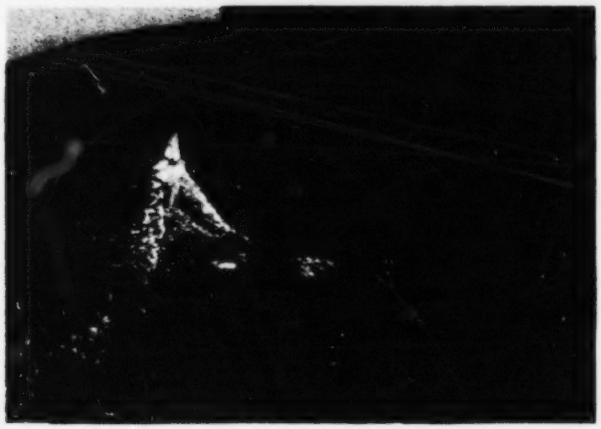
Plate 1. Changes in eye appearance with storage time and temperature. Note the black pupil and clear cornea of the fish stored 12 hrs at 0°C (Photograph 6) and the sunken, cloudy appearance of the eye of the fish stored 48 hrs at 15°C (Photograph 7).



Photograph 8.
(25232.12A)



Photograph 9.
(25231.29)



Photograph 10.
(25232.5A)

Plate 2. Gill appearance of fish stored at 0°C (Photograph 8), 7°C (Photograph 9) and 15°C (Photograph 10) for 48 hrs. Note the heavy mucoid appearance at 7°C and marked discolouration of the gill tissue at 15°C.

Photograph 11. (25228.20)

Photograph 12. (25232.12)

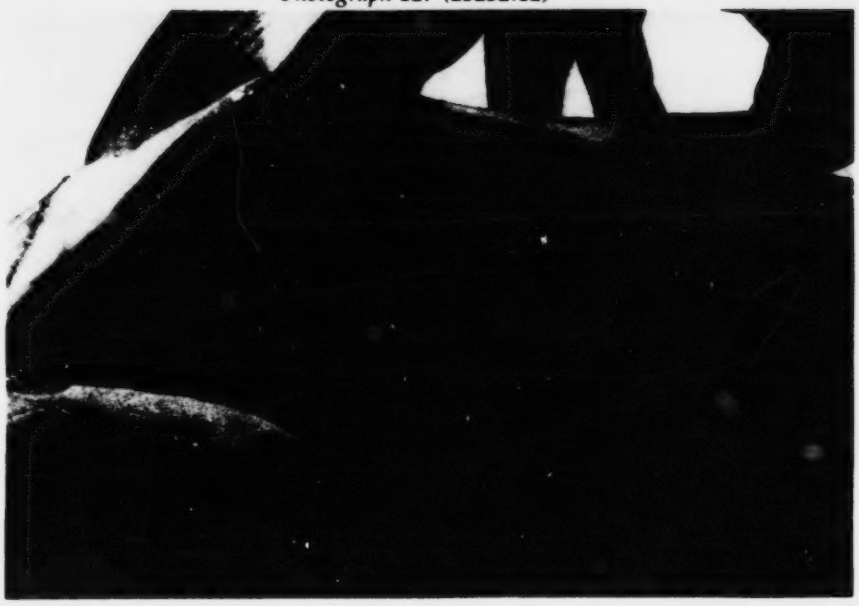
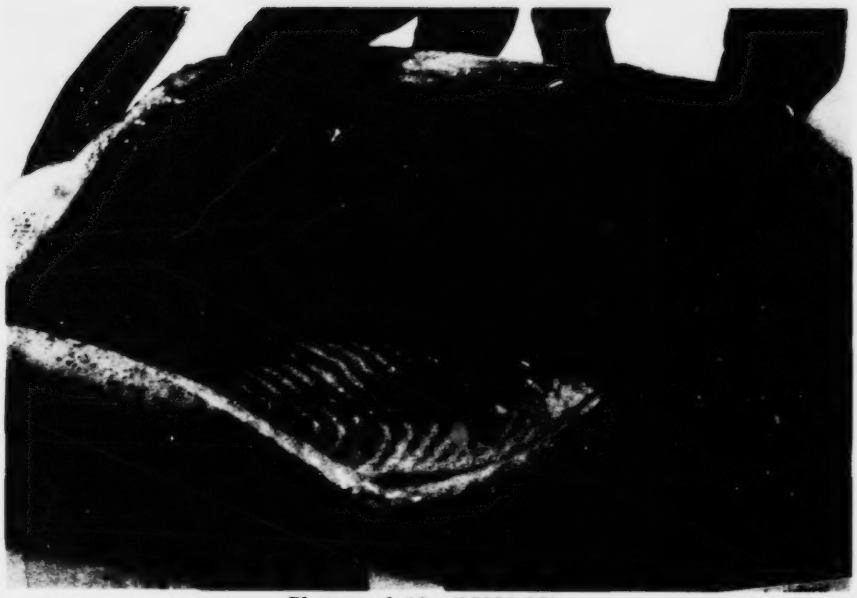


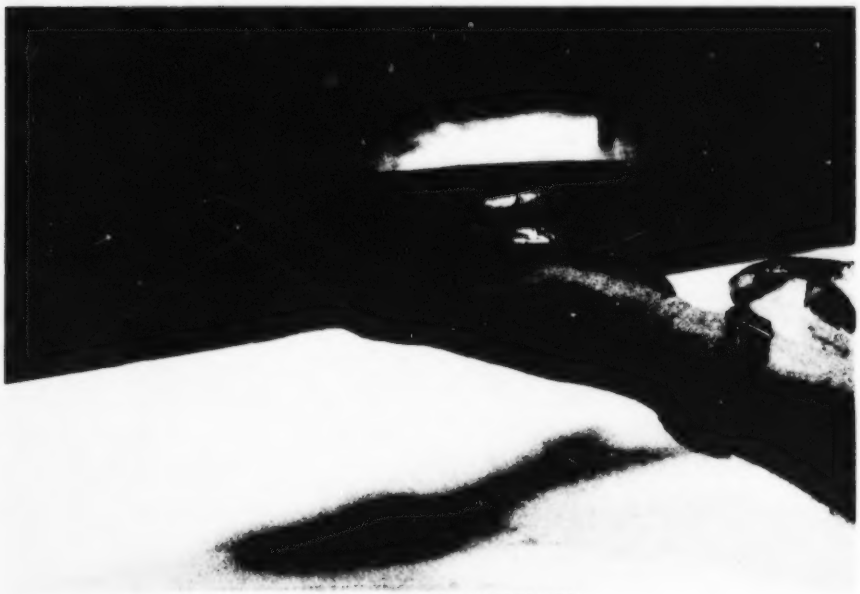
Plate 3. Belly cavity appearance of fish held gutted at 0°C for 12 hrs (Photograph 11), and 48 hrs (Photograph 12). Although there is a slight loss in flesh glossiness and colour after 48 hrs, there is no obvious appearance of belly-burn (cf. Photographs 13 and 14 in Plate 4).



Photograph 13. (25231.22)

Photograph 14. (25231.33)

Plate 4. Belly cavity appearance of fish held in the round at 7°C (Photograph 13), and 15°C (Photograph 14) for 48 hrs. Note the slight (Photograph 13) and marked (Photograph 14) disintegration of the peritoneal lining. Also note the discolouration and protruding rib bones of the fish stored at 15°C.



Photograph 15. (25228.13)

Plate 5. A farmed chinook salmon still in rigor after being stored for 12 hrs in ice (cf. Photographs 16 and 17 in Plate 6).

Photograph 16. (25232.15)

Photograph 17 (25232.7)

Plate 6. Effect of storage temperature on muscle rigidity. Note the limp nature of the fish stored for 48 hrs at 15°C (Photograph 17) compared to a similar fish stored for the same period at 0°C (Photograph 16).